Medium Modifications of Charm and Charmonium in Heavy-Ion Collisions

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Heavy-flavor bound states constitute a valuable probe of the hot/dense strongly interacting matter formed in relativistic collisions of heavy nuclei. *E.g.*, due to color Debye screening, J/ψ suppression was suggested as a signature of a deconfined medium since tightly bound $c\bar{c}$ states are presumably robust in a hadron gas (HG). However, more recently it has been realized that c-quark reinteractions in the medium can lead to regeneration of charmonium states through c-$\bar{c}$ coalescence, especially if charm production is abundant (*e.g.*, $N_{c\bar{c}}\sim$10-20 in central *Au-Au* collisions at RHIC).

Further insights into charm(onium) properties at finite temperature T have recently been provided by lattice QCD (LQCD) calculations which indicate *(i)* a continuous reduction of the open-charm threshold with increasing matter temperature and *(ii)* the survival of low-lying charmonia ($\eta_c, J/\psi$) up to $\sim 2\,T_c$.

We here present an approach to charmonium production at SPS and RHIC [1, 2] in which in-medium charm properties are modeled in accord with LQCD results and implemented into a kinetic rate equation, solved for a schematic thermal fireball expansion. It enables a simultaneous treatment of charmonium dissociation and regeneration throughout the evolution of the system.

At SPS energies ($\sqrt{s}$=17.3 AGeV), primordial charmonium production is large compared to charmonium equilibrium abundances implying little regeneration. The centrality dependence of the J/ψ over Drell-Yan ratio in *Pb-Pb* collisions is well reproduced and QGP formation is characterized by J/ψ *suppression*. The consequences of in-medium effects are particularly pronounced in the ψ'/ψ ratio, cf. the upper panel of Fig. 1. With vacuum D-meson masses (dashed line) our calculation underestimates ψ' suppression. The calculation including medium effects (full line) improves the agreement with NA50 data substantially, which is a direct consequence of the reduction of the $D\bar{D}$ threshold in the HG, opening the $\psi' \to D\bar{D}$ decay channel. The ψ' data set (including *p-A* collisions) has been reanalyzed by NA50 (diamonds), deducing a stronger nuclear absorption of the ψ'. Our calculation with the correspondingly updated values of $\sigma_{\rm nuc}$ is shown by the dash-dotted line, confirming the need for in-medium effects to reproduce the ψ'/ψ ratio.

Our calculations at full RHIC energy ($\sqrt{s} = 200$ AGeV) are compared to published PHENIX data in the lower panel of Fig. 1. Contrary to SPS, the J/ψ yield in central *Au-Au* collisions (full curve) is dominated by regenerated J/ψ's (dash-dotted curve) while primordial J/ψ's are almost completely suppressed (dashed line). The uncertainty linked to our treatment of in-medium effects is reflected by the band corresponding to $-250 < \Delta m_D(T_c) < -80$ MeV, with stronger in-medium effects resulting in a smaller J/ψ yield.

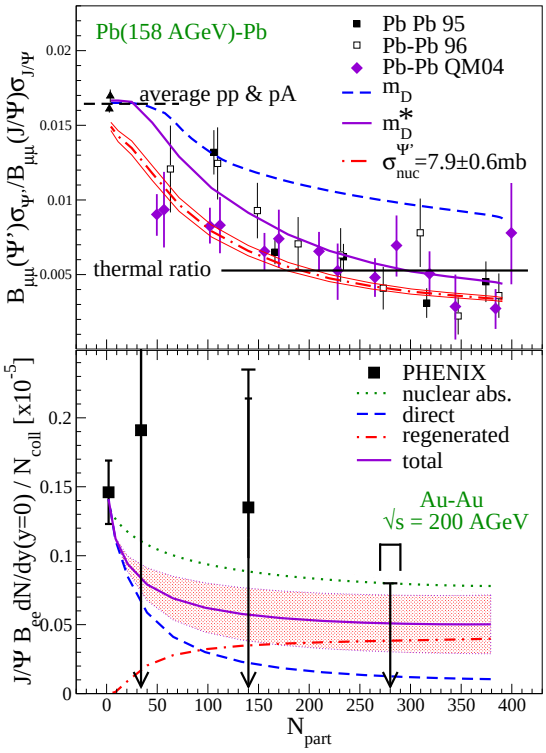

FIG. 1: Upper panel: ψ'/ψ ratio as a function of centrality at SPS *Pb*(158 AGeV)-*Pb* collisions. Lower Panel: Centrality dependence of $J/\psi/N_{\rm coll}$ at mid-rapidity vs. $N_{\rm part}$ in 200 AGeV *Au-Au* at RHIC.

We find that QGP formation manifests itself by J/ψ suppression at SPS energies and by J/ψ regeneration at RHIC, where run-4 data are expected to give important insights. In-medium effects have so far proved to be essential to understand the centrality dependence of the ψ'/ψ ratio at SPS. Complementary studies of charmonium transverse momentum distributions, as well as charmonium and bottomonium production at LHC, will provide further scrutiny of the proposed approach.

[1] L. Grandchamp, R. Rapp, and G. E. Brown (2004), to appear in Phys. Rev. Lett.

[2] L. Grandchamp, R. Rapp, and G. E. Brown (2004), to appear in J. Phys. G.